Leptoquark search at the Tevatron

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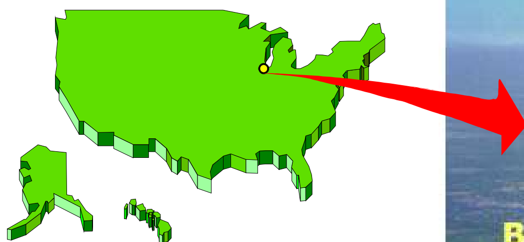
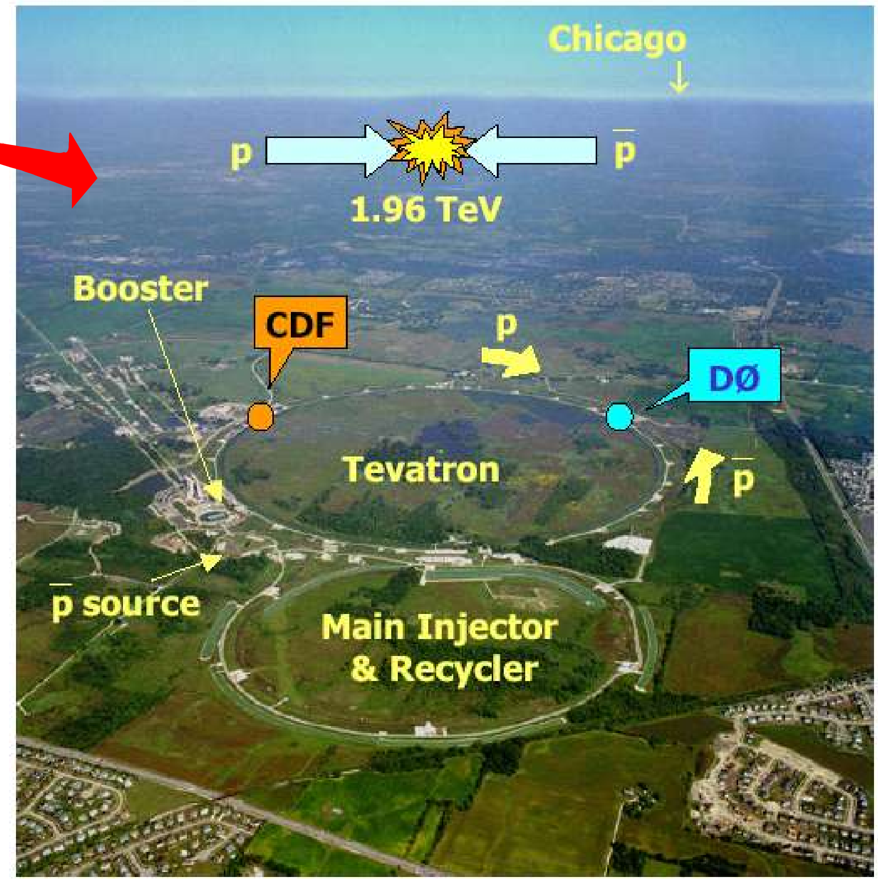
Introduction

- Leptoquarks have both lepton and quark flavor
  - Connection of lepton and quark sector
  - Predicted by many extensions of the Standard Model
    - GUT, extended gauge models, compositeness
  - Leptoquark-like couplings in R-parity Violation SUSY
- Description with effective couplings
  - invariant under $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$
  - Conserves lepton and baryon number separately (proton lifetime)
  - Couples only to one lepton and one quark family (FCNC)
  - Scalar and vector leptoquarks are possible
  - Only limits for scalar leptoquarks are shown
    - scalar LQ have lower cross-sections ($\Rightarrow$ limit also valid for vector LQ)
    - scalar LQ are less model dependent

The Tevatron

at Fermilab
near Chicago



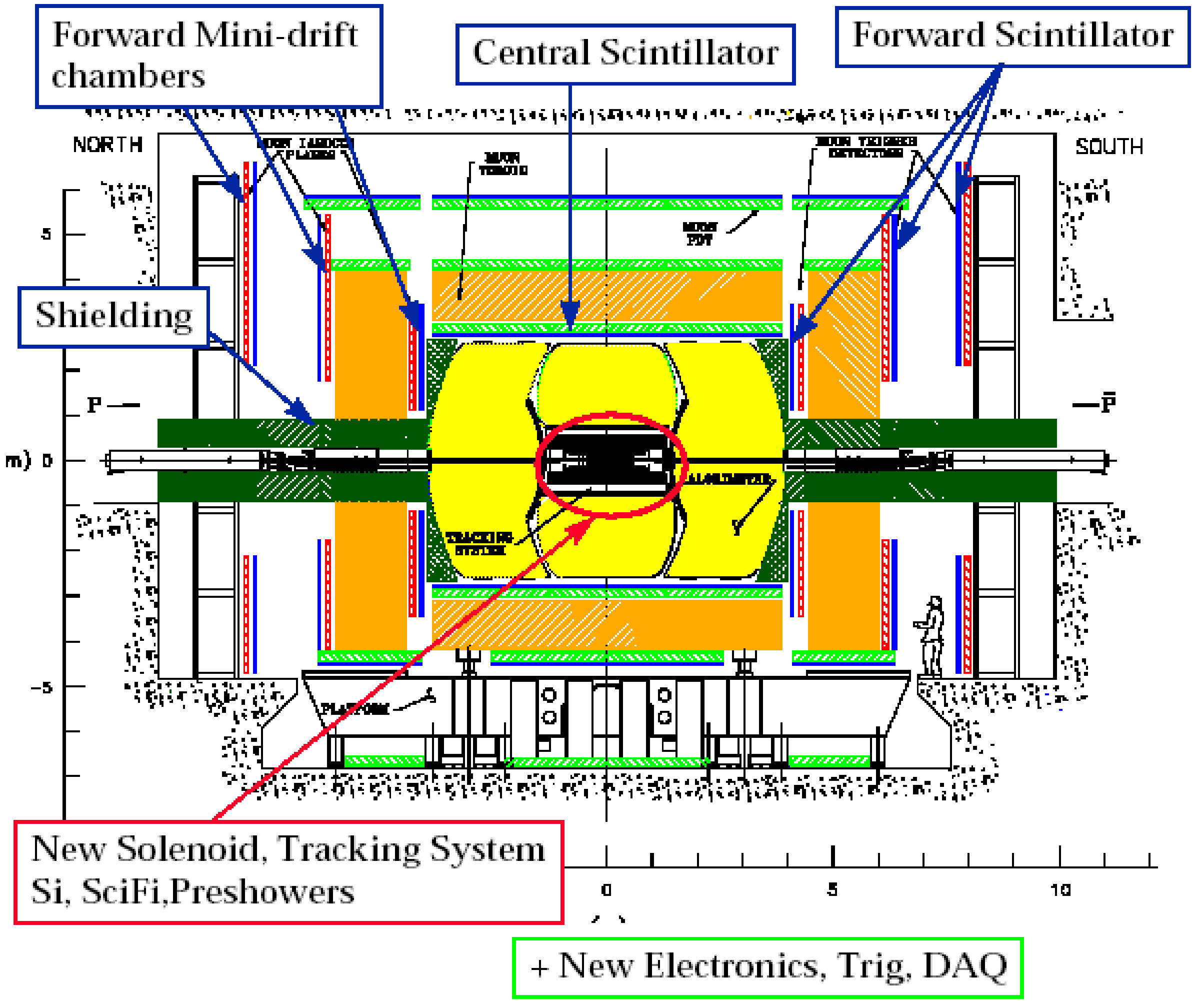


Run I: 1992-1996
100 pb^{-1} at $\sqrt{s}$ = 1.8 TeV

Run II: since 2001
proton antiproton collisions
at $\sqrt{s}$ = 1.96 TeV

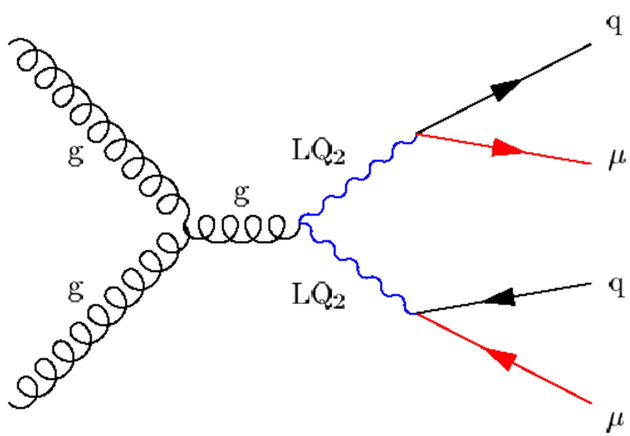
Data sets of analyses shown
range from 72 pb^{-1} to 200 pb^{-1}

The DØ Run II Detector



- Jet
  - Calorimeter
- Electrons
  - Signal mostly in the electromag. calorimeter
  - Track
- Muon
  - Track
  - Muon system
- Missing energy
  - calorimeter corrected for muons and jet energy scale

Leptoquarks at the Tevatron



- pair produced by strong coupling
  - large cross-section
  - cross-section is model independent
- the LQ decays either into a quark and a charged lepton (with probability β) or a quark and a neutrino

Possible signature:

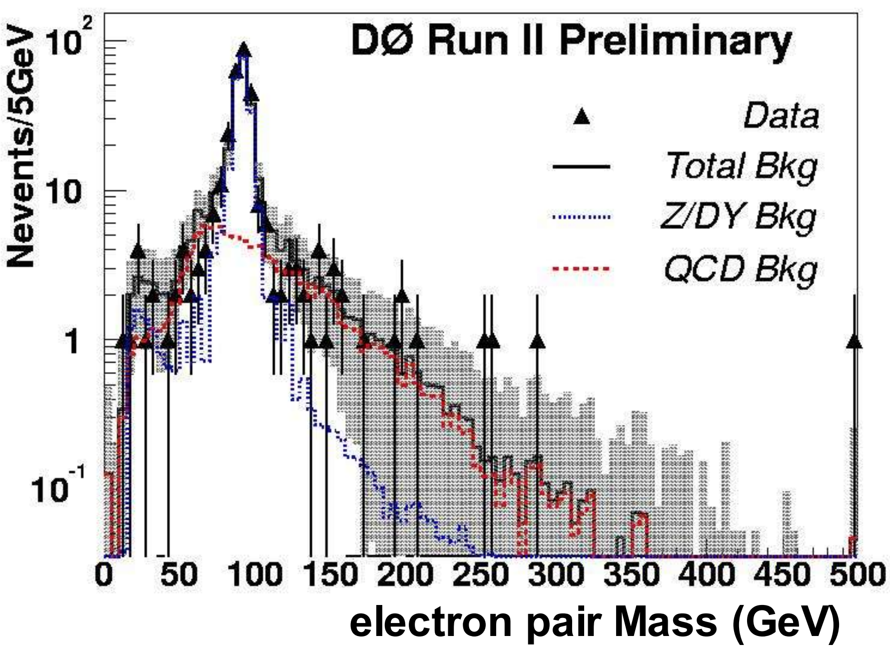
- 2 jets + 2 leptons (both e or both μ) no missing energy
- 2 jets + 1 lepton + missing energy
- 2 jets + missing energy

Interesting leptoquark masses are ~ 200 GeV
⇒ All objects are high energetic.

2 Jets and 2 Electrons

2 jets with E_T > 20 GeV

2 electrons with E_T > 25 GeV



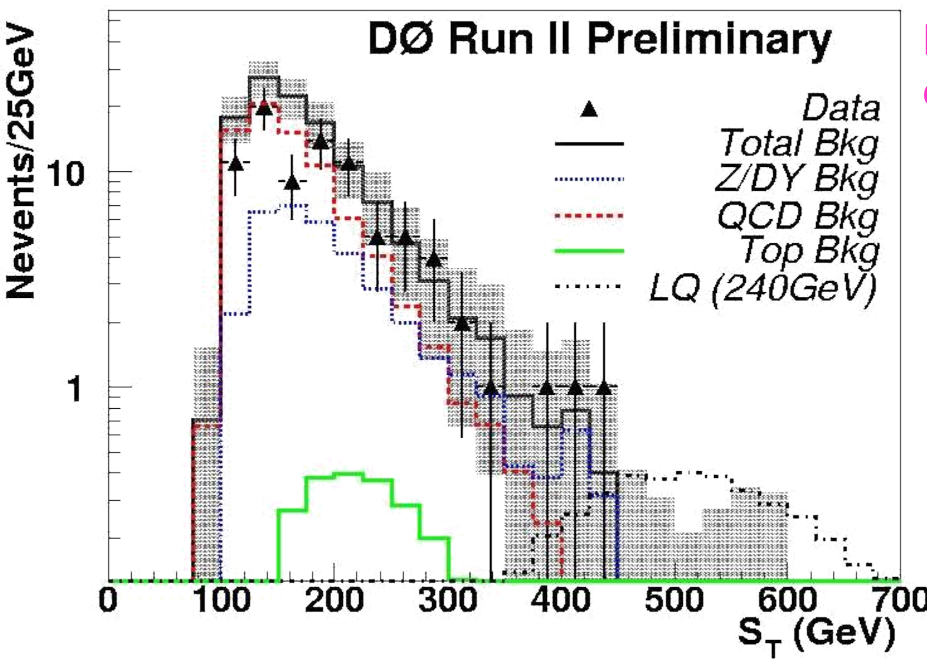
$\Rightarrow$ veto on Z^0 mass region

Main backgrounds

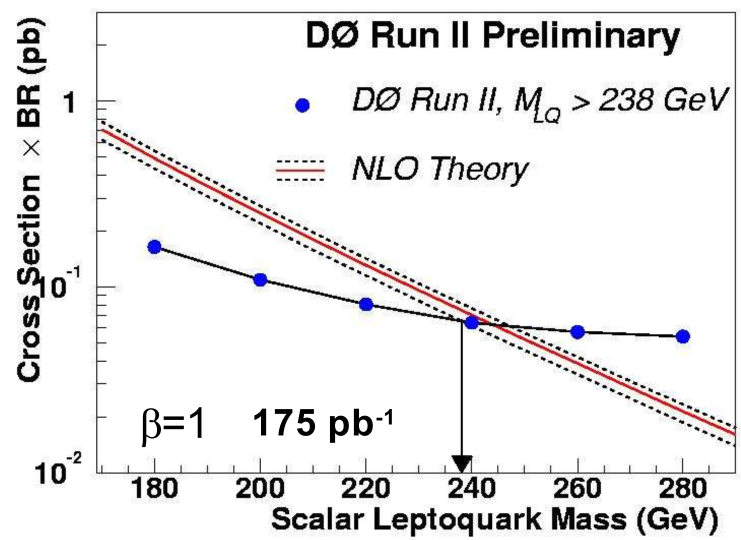
- 2 jets+2 real electrons from Z^0/Drell-Yan events.
  - estimated from MC
- 2 jets and 2 fake electrons from fake ("electron like") jets.
  - estimated from data with 4 jets and fake probability.

2 Jets and 2 Electrons

Exploit high energy of objects: $S_T = E_T^{Jet\_1} + E_T^{Jet\_2} + E_T^{e\_1} + E_T^{e\_2}$



Extract mass limit from comparison of predicted cross-section and crosssection limit



Select cut to optimize expected limit

(or expected discovery significance)

0.4 ± 0.1 background events expected
28% Signal efficiency
0 events observed.

CDF preliminary 200 pb^{-1}

$M_{LQ}^{scalar}(1^{st}\ Gen.) > 230\ GeV \quad (\text{for } \beta = 1)$

2 Jets, 1electron, and missing energy

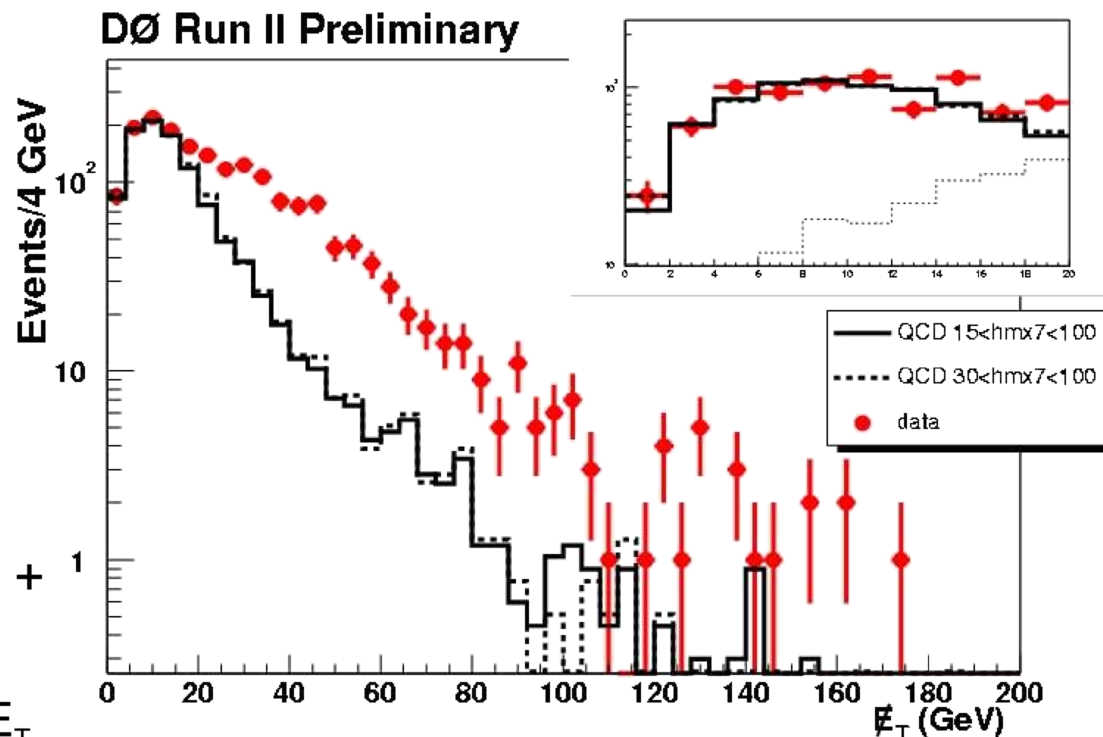
2 jets with E_T > 25 GeV

1 electron with E_T > 35 GeV

missing E_T > 30 GeV

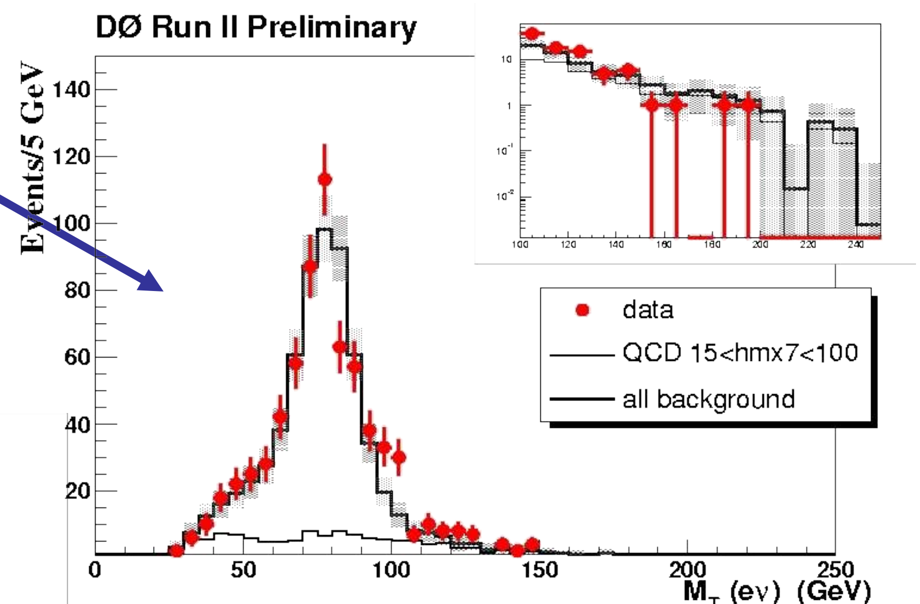
Main background

- W+jets
- fake electron (from γ or jet) + 2 jets
  - Normalize at low missing E_T



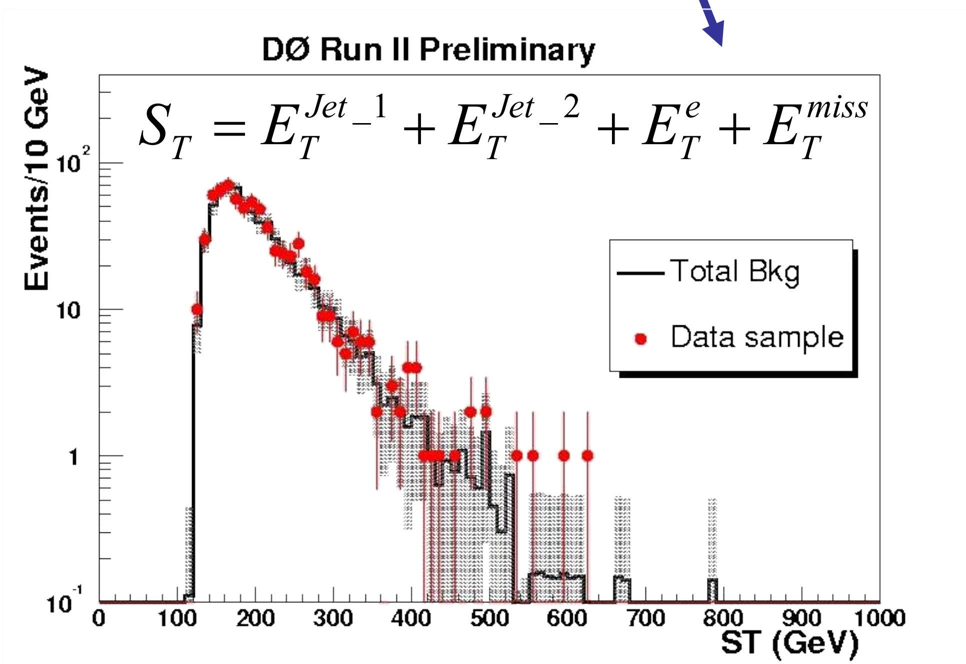
2 Jets,1 electron, and missing energy

Cut on M_T (M_T>130 GeV) to veto W+Jets



2 events observed
4.78 ±0.78 expected

Cut on S_T (S_T >330 GeV) to exploit high energy of objects.



DØ preliminary 175 pb^{-1}

$$M_{LQ}^{scalar}(1^{st}\ Gen.) > 194\ GeV \quad (\text{for } \beta = 0.5)$$

CDF preliminary 72 pb^{-1}

$$M_{LQ}^{scalar}(1^{st}\ Gen.) > 166\ GeV \quad (\text{for } \beta = 0.5)$$

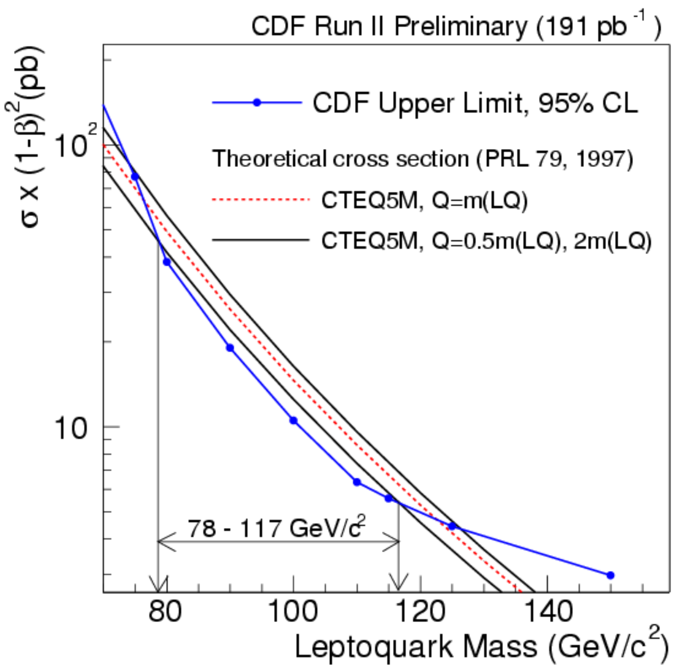
2 Jets and Missing Energy

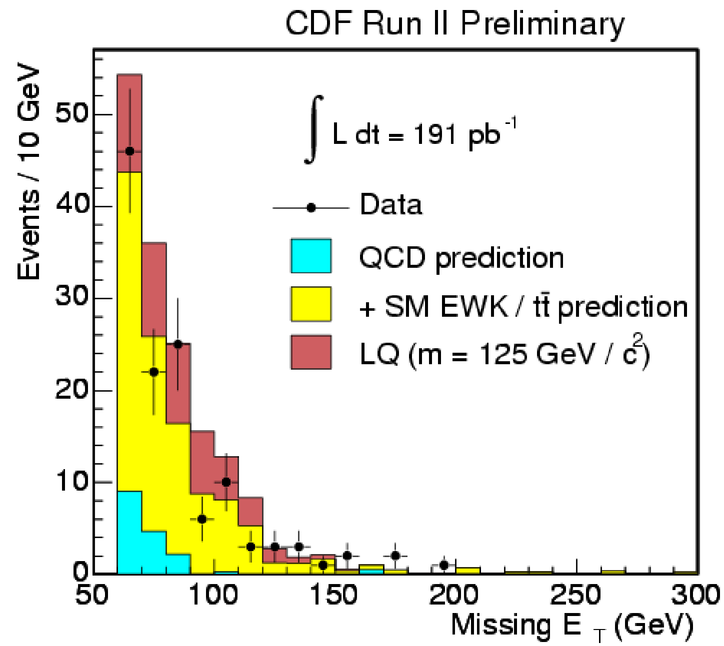
2 jets with E_T > 20 GeV

missing E_T > 60 GeV

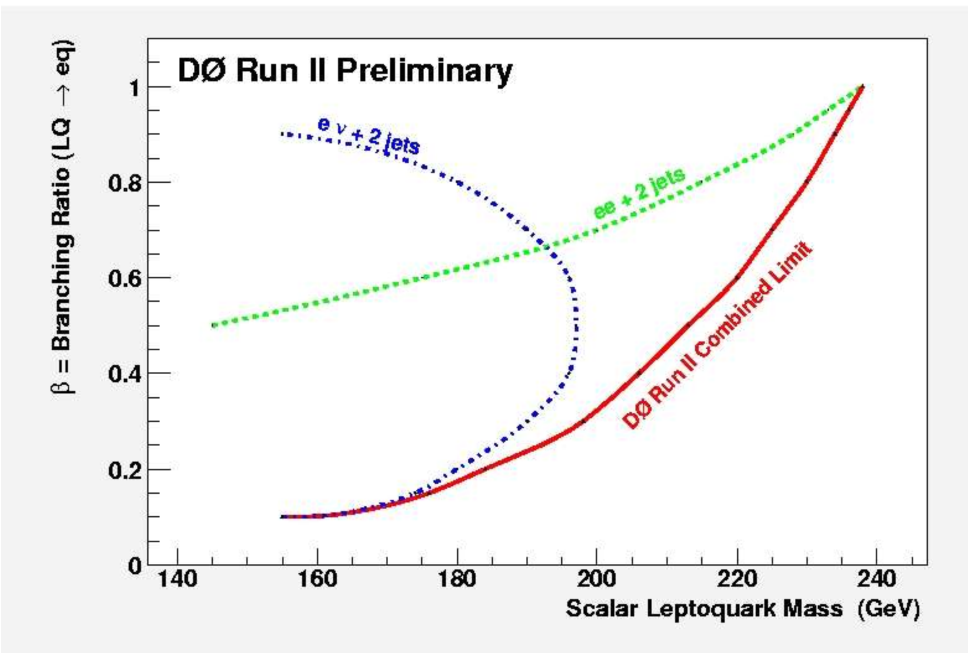
124 events observed

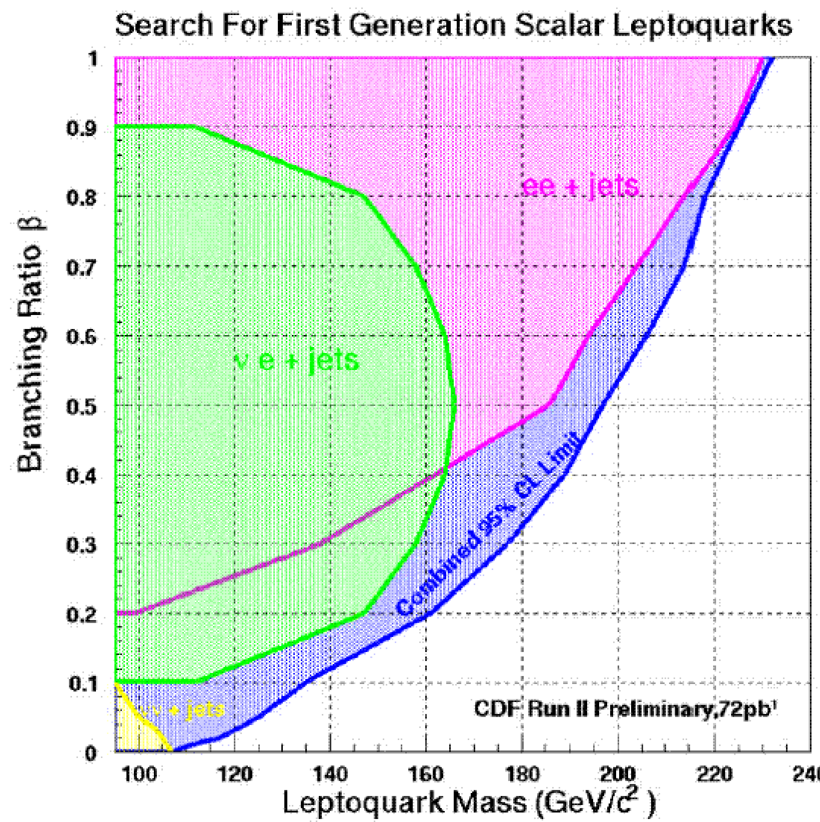
118±14 expected





First-Generation LQ Limits





2 Jets and 2 Muons

2 jets with E_T > 30 GeV, 15 GeV

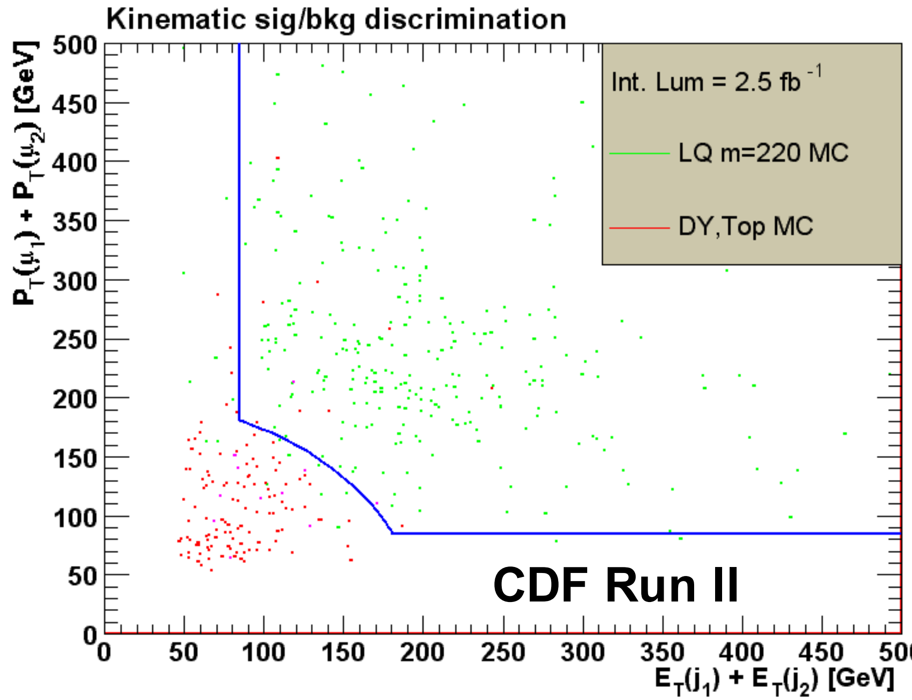
2 muons with p_T > 25 GeV

Main background:

Z^0/Drell-Yan events

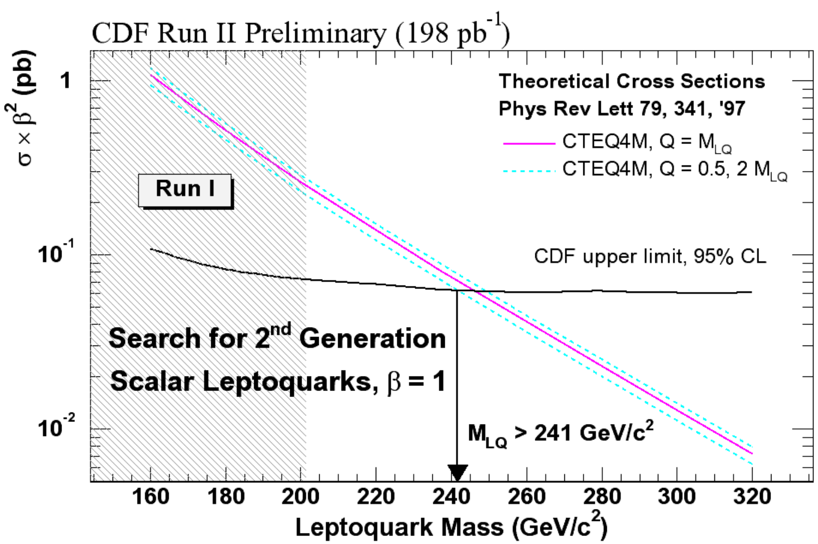
$\Rightarrow$ veto on $M_{\mu\mu}$ < 15GeV and

75 GeV < $M_{\mu\mu}$ < 105GeV



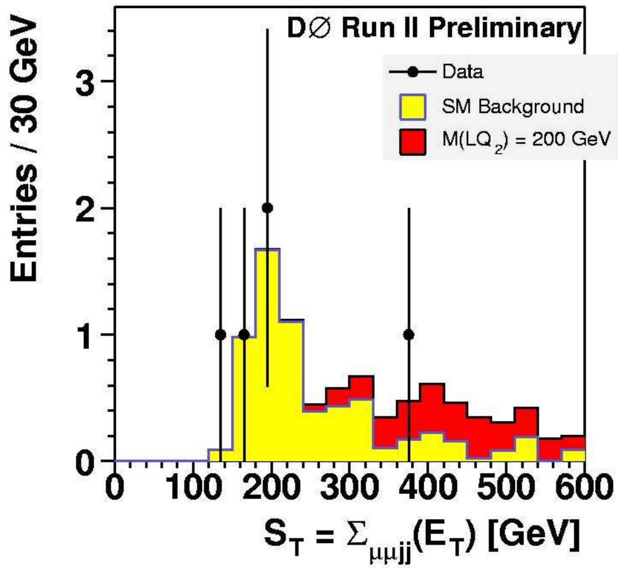
2-dim cut on Jet E_T and muon p_T

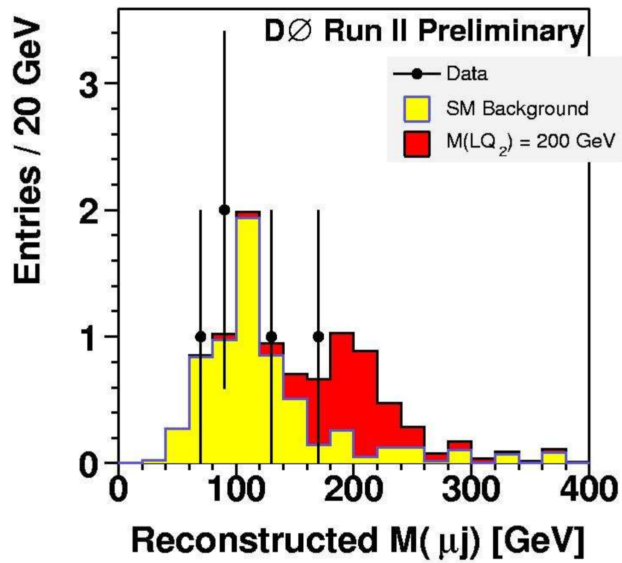
2 events observed
3.17 ±1.17 expected



2 Jets and 2 Muons

Different ways to exploit the LQ decay-kinematics have been studied





Reconstructed LQ Mass

- pick μ-jet combination for which the mass difference between the 2 pairs is smallest
- Use the average of the two masses

DØ preliminary 104 pb^{-1}

$$M_{LQ}^{scalar}(2^{nd}\ Gen.) > 186\ GeV \quad (\text{for } \beta = 1)$$

Conclusions and Outlook

- Hadron collider is a good place to search for leptoquark pairs
  - Leptoquark pairs can be produced in strong interactions
  - Highly energetic leptons and jets result in clean signatures
- Limits for scalar leptoquarks have surpassed Run I results
  - publications are in preparation
- Outlook
  - work on missing channels
  - Sensitivity will increase with integrated luminosity (there is a lot of separation power left to exploit.)